

PARIS

ORSAY

Série A

N° D'Ordre : 1324

ETUDE DES REACTIONS $KN \rightarrow \Lambda\pi\pi$ DE 0,4 A 1,4 GeV/c

ARTICLE PRINCIPAL

recouvrant en partie la thèse de Doctorat ès-Sciences Physiques
enregistrée au C.N.R.S. sous le Numéro A 10 068

PREVOST Jacques

Soutenue le 14 Juin 1974 à l'UNIVERSITE DE PARIS SUD (Centre d'ORSA
devant le Jury

MM. A. BERTHELOT Président

J. TEILLAC

R. BARLOUTAUD

A STUDY OF THE REACTIONS $\bar{K}N \rightarrow \Sigma(1385)\pi$ BETWEEN 0.6 AND 1.2 GeV/c[†]

CERN – Heidelberg – Saclay – Collaboration

J. PREVOST, R. BARLOUTAUD, J. GRISELIN, F. PIERRE
and J.P. PORTE*

Département de Physique des Particules Élémentaires, CEN-Saclay

C. BRICMAN, J.O. PETERSON and J. MEYER
CERN, Geneva

H. FILTHUTH and E. KLUGE
Institut für Hochenergiephysik der Universität, Heidelberg

Received 26 July 1973

(Revised 15 October 1973)

Abstract: An energy-dependent partial-wave analysis of the reaction $\bar{K}N \rightarrow \Sigma(1385)\pi$ has been performed in the energy region lying between 1.65 and 1.85 GeV. The resonant amplitudes of seven well known Y^* resonances have been determined, and used to compute the corresponding (8)⊗(10) SU (3) coupling constants.

1. Introduction

For several years Y^* spectroscopy has been extensively studied through $\bar{K}N$ formation experiments. Although the experimental data are still far from being as reliable as those from πN experiments, many resonances have obtained a definite status because they have often been seen in both the elastic and the inelastic two-body channels, such as $\Lambda\pi$ or $\Sigma\pi$. However, for most of them, the two body decays do not saturate unitarity, implying decays into quasi two body or many body channels, which are poorly known. This paper reports results on the decay into $\Sigma(1385)\pi$ of the well accepted Y^* resonances in the mass region between 1.6 and 1.85 GeV.

First we present data on the total cross sections of the reactions

$$K^- p \rightarrow \Lambda\pi^+ \pi^-, \quad (1)$$

$$K^- n \rightarrow \Lambda\pi^- \pi^0, \quad (2)$$

from 0.43 to 1.43 GeV/c. Then we show that both reactions are strongly dominated by the production of $\Sigma(1385)$, suggesting that they can be interpreted in terms of the quasi two-body channels $\Sigma^\pm(1385)\pi^\mp$ or $\Sigma^0(1385)\pi^0$ for (1) and (2) respectively.

[†] This work is part of a thesis by J. Prevost submitted to Faculté d'Orsay in fulfillment of the requirements for Doctorat d'État.

* Present address: CERN, Geneva.



These quasi two-body channels are analysed in energy dependent partial waves according to the Deler-Valladas version [1] of the isobaric model, for K^- momenta in the interval 0.6 to 1.15 GeV/c in order to find the amplitudes at resonance for the well-known Λ and Σ states in the energy interval under consideration.

Finally, we looked at the compatibility of our results with a simple SU(3) model. A reasonable agreement with the model is obtained for the $\frac{3}{2}^-$ nonet and the $\frac{1}{2}^-$ and $\frac{5}{2}^+$ octets. Some problems with the $\frac{5}{2}^-$ octet will be discussed.

2. Experimental results

2.1. Data

The reactions (1) and (2) have been studied as part of a systematic analysis of the $\bar{K}N$ interactions made by the CERN-Heidelberg-Saclay Collaboration. 18 600 events of reaction (1) were obtained for incident momenta between 0.43 and 1.43 GeV/c, and 2600 events of reaction (2) at 8 incident momenta between 0.70 and 1.15 GeV/c.

Experimental details concerning this study have already been published [2–4]. The events of reaction (1) constitute a very pure sample [2, 4], whereas those of reaction (2) may be ambiguous with $\Sigma^0\pi^-\pi^0$. However, for this reaction a statistical separation can be made to obtain the total cross section, which is all we used from it in our subsequent analysis. The data for reaction (1) between 1.12 and 1.43 GeV/c presented here are new; they have been treated with the same methods as the old data.

2.2. Cross sections

The determination of the cross sections σ_1 and σ_2 for reactions (1) and (2) respectively between 0.43 and 1.23 GeV/c has been described in references [2–4]. For the new data, the cross sections of reaction (1) are presented in table 1. These results are compiled in figs. 1a and 1b as a function of incident momentum, together with other published data [5] between threshold and 2 GeV/c. The agreement between all experimental data is generally good, with the exception of the high energy points of reference [6] for reaction (2) between 0.70 and 0.90 GeV/c which are definitely higher than those of this experiment.

The main features which emerge from figs. 1a and 1b are:

For reaction (1), the occurrence of a broad enhancement between the center-of-mass energies 1.65 and 1.85 GeV. This includes the positions of four well established resonances with $I=0$, $\Lambda(1670, \frac{1}{2}^-)$, $\Lambda(1690, \frac{3}{2}^-)$, $\Lambda(1815, \frac{5}{2}^+)$, $\Lambda(1830, \frac{5}{2}^-)$ and three with $I=1$, $\Sigma(1660, \frac{3}{2}^-)$, $\Sigma(1750, \frac{1}{2}^-)$ and $\Sigma(1765, \frac{5}{2}^-)$.

For reaction (2), the cross section rises regularly between 1.60 and 1.76 GeV, then decreases slowly in the region lying between 1.80 and 2.10 GeV.

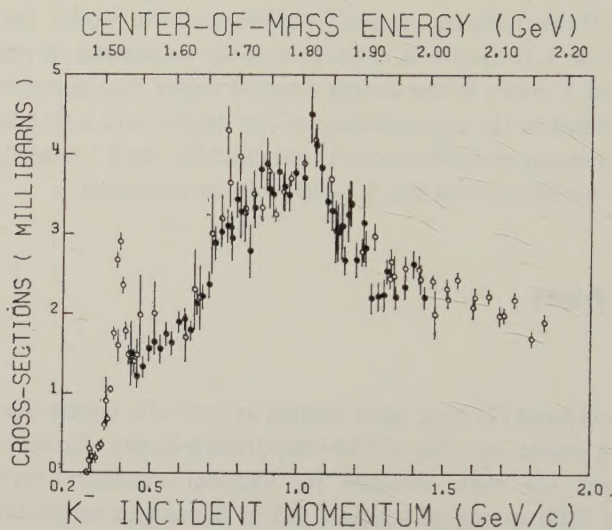


Fig. 1a. Cross section for the reaction $K^-p \rightarrow \Lambda\pi^+\pi^-$ as a function of the K^- incident momentum. Full circles refer to the C.H.S. experiment ([2, 4] and table 1); open circles represent other published data [5].

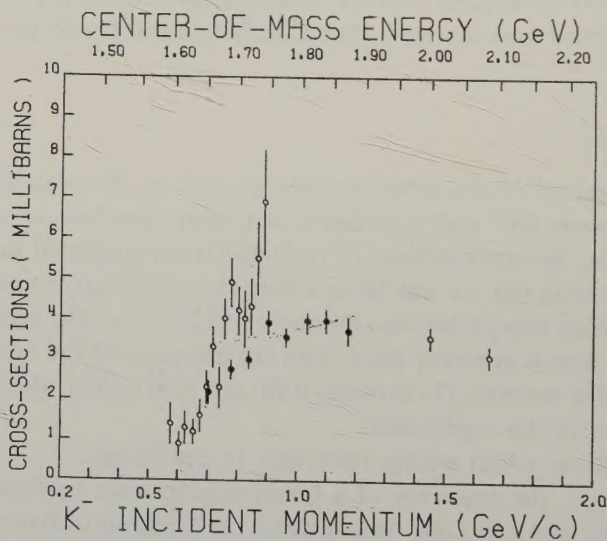


Fig. 1b. Cross section for the reaction $K^-n \rightarrow \Lambda\pi^-\pi^0$ as a function of the K^- incident momentum. Full circles refer to the C.C.S. experiment [3]; open points are taken from refs. [6, 8].

Table 1

Cross section for reaction $K^-p \rightarrow \Lambda \pi^+ \pi^-$: new data between 1.130 and 1.430 GeV/c

Incident momentum (GeV/c)	Cross section (mb)	
	σ_1	$d\sigma_1$
1.138	3.04	0.21
1.161	2.67	0.18
1.179	3.40	0.28
1.201	2.68	0.22
1.233	2.83	0.22
1.253	2.20	0.18
1.276	2.22	0.17
1.296	2.24	0.20
1.305	2.54	0.15
1.336	2.22	0.14
1.367	2.34	0.15
1.396	2.63	0.17
1.434	2.21	0.14

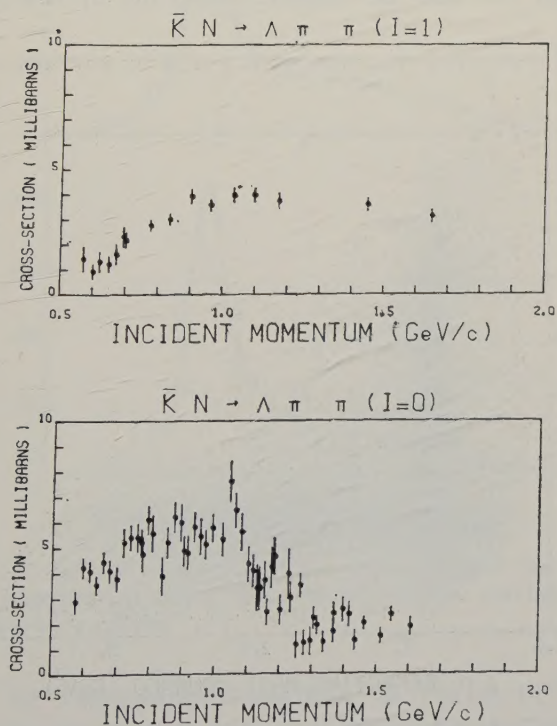


Fig. 2. $I=0$ and $I=1$ contributions to the cross sections $\bar{K}N \rightarrow \Lambda \pi \pi$.

The contributions of isospins 0 and 1 to the cross section of the reaction $\bar{K}N \rightarrow \Lambda\pi\pi$ are easily deduced from these cross sections:

$$\sigma(I = 1) = \sigma_2,$$

$$\sigma(I = 0) = 3\sigma_1 - 1.5\sigma_2.$$

They are plotted in fig. 2 as a function of incident momentum, using data which come from our measurement of the cross section for (1) and (2), plus for (1), eight values obtained in ref. [7] and for (2), the six lowest points of ref. [6] and the results of [8]. It can be seen that $\sigma(I = 1)$ has a smoother behaviour than $\sigma(I = 0)$, where more resonances are expected. Below 1.2 GeV/c, $\sigma(I = 1)$ is smaller than $\sigma(I = 0)$, while above this momentum it becomes higher; above a center-of-mass energy of 1.9 GeV, this suggests a stronger coupling to $\Lambda\pi\pi$ of the isovector resonances, which may be explain by an increasing contribution of the $\Lambda\rho$ final state.

2.3. Dalitz plots

From now on, only data from our experiments have been used. Throughout the whole momentum range the $\Lambda\pi^+\pi^-$ and $\Lambda\pi^-\pi^0$ final states appear to be dominated by the production of $\Sigma(1385)$. This can be seen for reaction (1) on the scatter-diagram of the square of the $\Lambda\pi^+$ and $\Lambda\pi^-$ effective masses (fig. 3). It is nevertheless clear

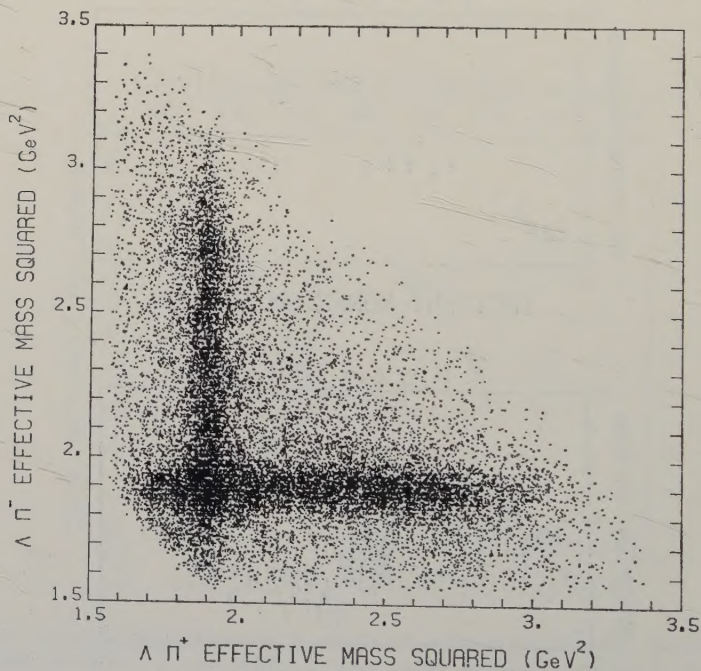


Fig. 3. Scatter-diagram of the square of the $\Lambda\pi^+$ and $\Lambda\pi^-$ effective masses for reaction (1) in the whole incident momentum range (0.43-1.43 GeV/c) (18 600 events).

that other quasi-two-body contributions to these final states cannot be excluded as e.g. $\Lambda\rho$, the threshold of which occurs around 1.15 GeV/c, and $\Lambda\sigma$, σ being a $J = I = 0$ $\pi\pi$ -system which is known to dominate low energy $\pi\pi$ scattering. To reduce as much as possible these possible contributions, the analysis has been restricted to incident momenta lying between 0.6 and 1.15 GeV/c. In this momentum range, the distributions of the invariant masses $\Lambda\pi^\pm$ presented in fig. 4 show prominent peaks around 1.385 GeV. Therefore, we assume that reactions (1) and (2) can be described in terms of $\Sigma(1385)$ production alone. This is verified *a posteriori* by the good fits to the $\Lambda\pi$ mass spectra, of the distribution calculated from our partial wave analysis, as shown in fig. 4.

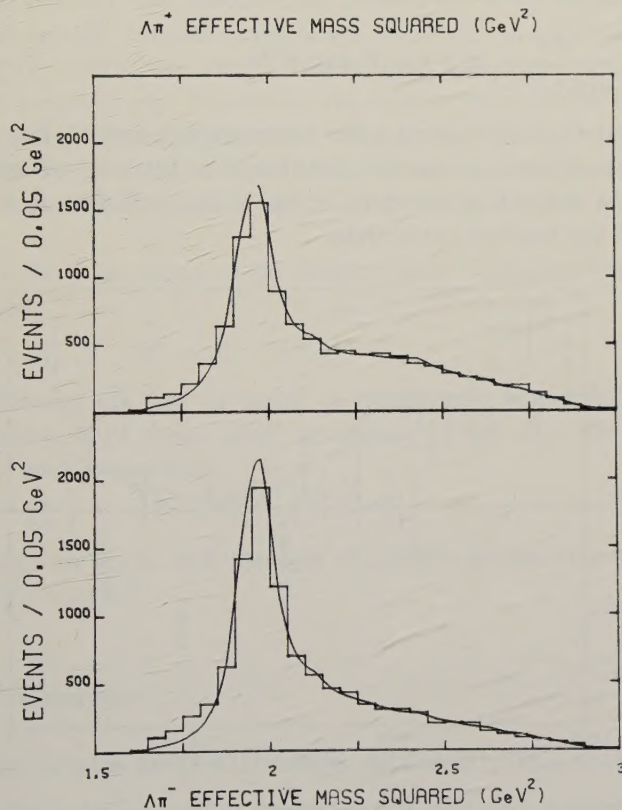


Fig. 4. Distribution of the $\Lambda\pi^+$ and $\Lambda\pi^-$ effective masses squared for reaction (1) in the incident momentum range (0.6-1.15 GeV/c). The curves represent the distributions calculated from the results of the partial-wave analysis.

The angle α^{*+} (α^{*-}) between the Λ and the π^- (π^+) in the $\Lambda\pi^+$ ($\Lambda\pi^-$) center-of-mass system is simply related to the position of the event in the Dalitz plot. In order to take into account the contributions of both $\Sigma^\pm(1385)$, in the distributions of

$\cos \alpha^{*+}$ and $\cos \alpha^{*-}$ each event has been weighted respectively by the quantities

$$\frac{BW^+}{BW^+ + BW^-} \quad \text{and} \quad \frac{BW^-}{BW^+ + BW^-},$$

representing the relative probabilities for this event to belong to the $\Sigma^\pm(1385)$ production reactions; $BW^\pm$ are the Breit-Wigner expressions for $\Sigma^\pm(1385)$ calculated with a mass of 1.383 GeV and a width of 0.036 GeV.

The resonance $\Sigma(1385)$ has a spin-parity $\frac{3}{2}^+$, so that the angular distribution of its decay into $\Lambda\pi$ can be described by an expression which is even in $\cos \alpha^*$ and has a maximum order 2. Therefore the sum of the $\cos \alpha^{*+}$ and $\cos \alpha^{*-}$ weighted distributions has been represented by:

$$\frac{dN}{d(\cos \alpha^{*+})} + \frac{dN}{d(\cos \alpha^{*-})} \simeq 1 + a_2 P_2(\cos \alpha^{*\pm}).$$

In this expression P_2 is the second order Legendre polynomial. For each incident momentum, the coefficient a_2 , whose value should be between -1 and 1 , has been determined by the method of moments. In fig. 5, the coefficient a_2 is seen to vary significantly with the incident momentum.

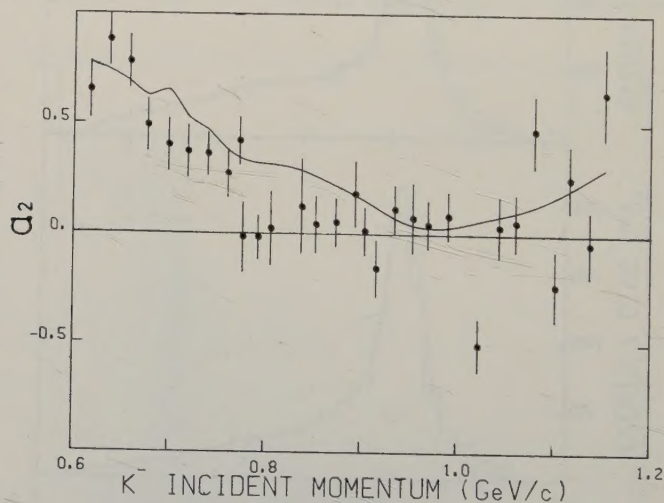


Fig. 5. Incident momentum dependence of the coefficient a_2 describing the angular decay distribution of $\Sigma^\pm(1385)$. The curve represents the results of the best fit in the partial wave analysis.

2.4. $\Lambda\pi\pi$ decay plane angular distribution

Each event of reaction (1) is kinematically characterized for a given incident momentum by:

- (i) the two coordinates in the Dalitz plot: $x = M^2(\Lambda\pi^+)$ and $y = M^2(\Lambda\pi^-)$;

(ii) the polar angle Θ , such as: $\cos \Theta = \hat{\xi} \cdot \hat{K}$, where $\hat{\xi}$ is the normal to the production plane: $\hat{\xi} = \hat{A} \times \hat{\pi}^+ / |\hat{A} \times \hat{\pi}^+|$; $\hat{K}$, $\hat{A}$ and $\hat{\pi}^\pm$ are unit vectors along the K^- , A and $\pi^\pm$ momenta in the center-of-mass system.

(iii) the azimuthal angle Φ such as: $\cos \Phi = \hat{b} \cdot \hat{K}_p$, $\hat{K}_p$ being the unit vector along the projection of $\hat{K}$ on the production plane and $\hat{b} = (\hat{\pi}^+ + \hat{\pi}^-) / |\hat{\pi}^+ + \hat{\pi}^-|$.

For each element of the Dalitz plot, the differential cross section in Θ and Φ can be expanded in terms of spherical harmonic functions:

$$\frac{d^4\sigma}{dx dy d(\cos \Theta) d\Phi} = \sqrt{4\pi} \lambda^2 \sum_{l,m} A_l^m(x, y) Y_l^m(\Theta, \Phi),$$

where λ^2 is the reduced wave length of the incident K^- in the center-of-mass system. As there is not enough statistics to divide the Dalitz plot in small parts, the complex coefficients $A_l^m(x, y)$ have been determined for each half of the plot, with $x > y$ (A_{l+}^m) and $x < y$ (A_{l-}^m) respectively. To do this, the method of moments has been used. It has been checked that the coefficients for which $l+m$ is odd are consistent with zero, as they should be by parity conservation. Moreover, since all coefficients with l greater than 4 are also compatible with zero, the expansion has been limited to the fourth order.

In order to show the effects of the isospin 0 and 1 contributions, the coefficients finally used are:

$$S_l^m = A_{l+}^m + A_{l-}^m, \quad D_l^m = A_{l+}^m - A_{l-}^m.$$

The S_l^m coefficients are free of terms of interference between the two isospins, whereas precisely only these terms contribute to the D_l^m . The coefficients are normalized in such a way that:

$$\sigma_1 = 4\pi \lambda^2 S_0^0.$$

They are plotted in fig. 6, as a function of incident momentum, together with the coefficients $S_0^0 = \sigma_2 / 4\pi \lambda^2$.

3. Partial-wave analysis

We attempt now to perform an energy dependent partial-wave analysis of the reaction

$$\bar{K}N \rightarrow \Sigma(1385)\pi \quad (3)$$

in the interval between 0.60 and 1.15 GeV/c.

With the explicit assumption that reactions (1) and (2) can be completely described by reaction (3)[†], we try to obtain the value and the sign of the resonant

[†] Throughout this paper, except in table 4, we have not taken into account the decay of $\Sigma(1385)$ into $\Sigma\pi$.

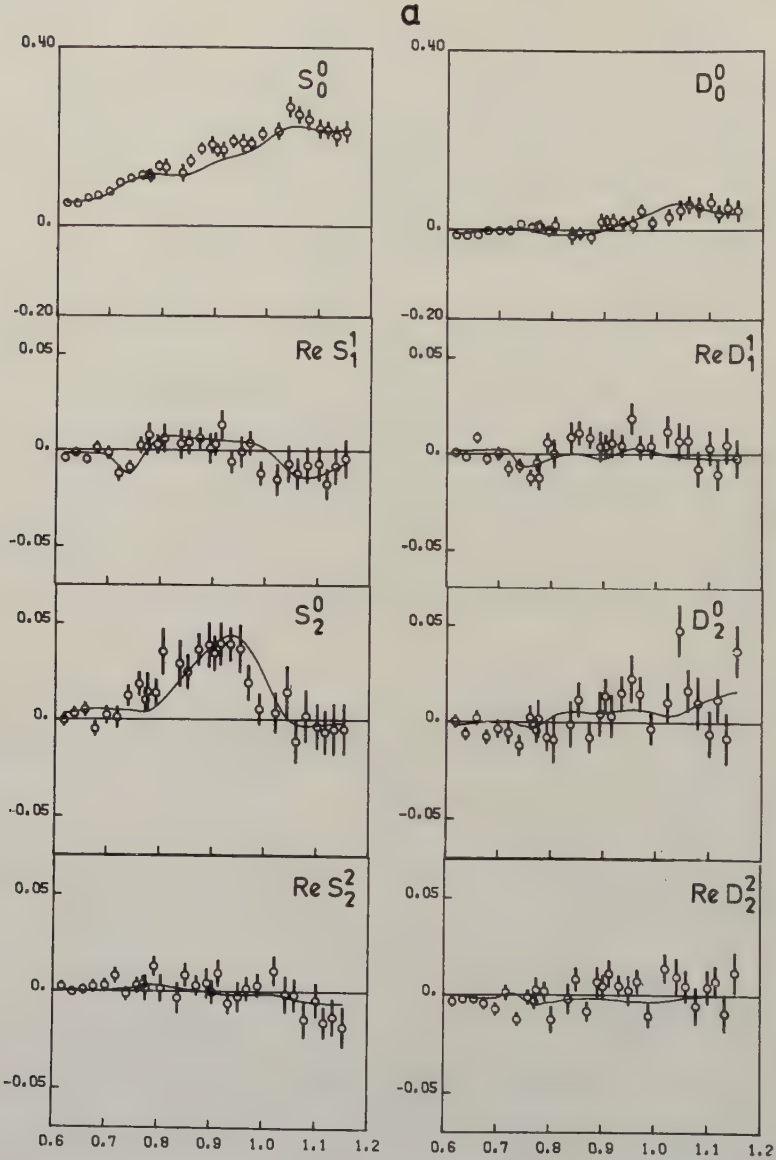


Fig. 6a

b

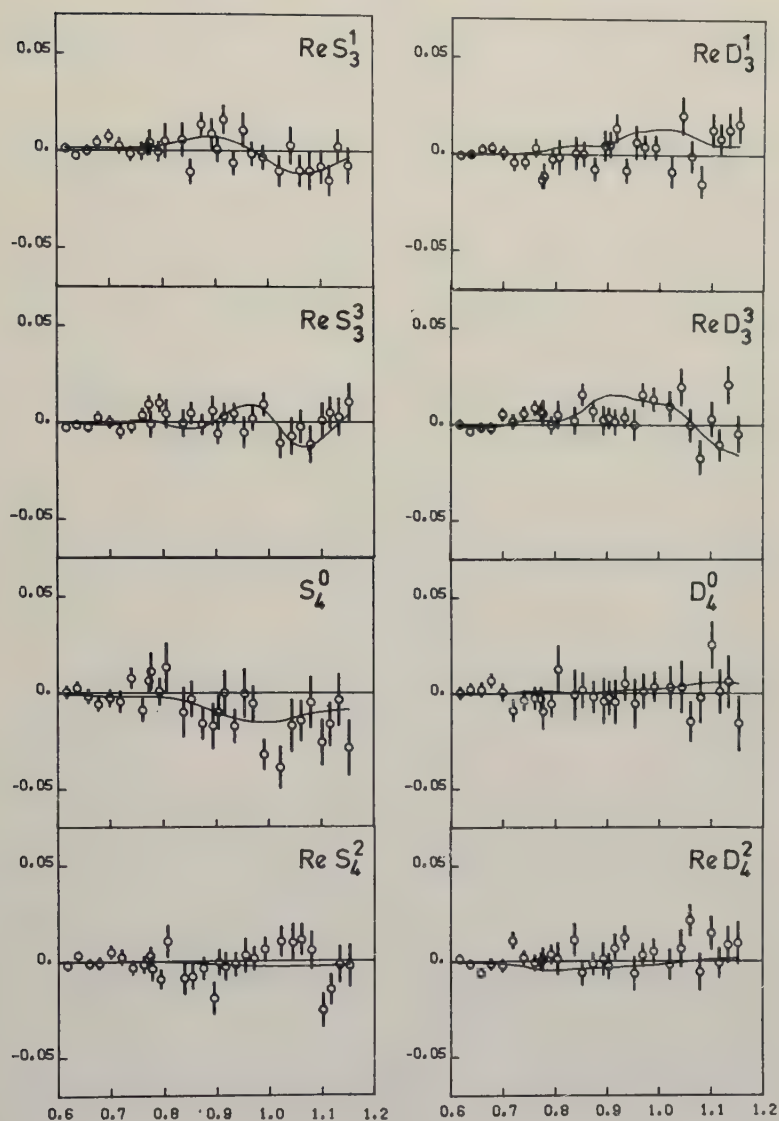


Fig. 6b

C

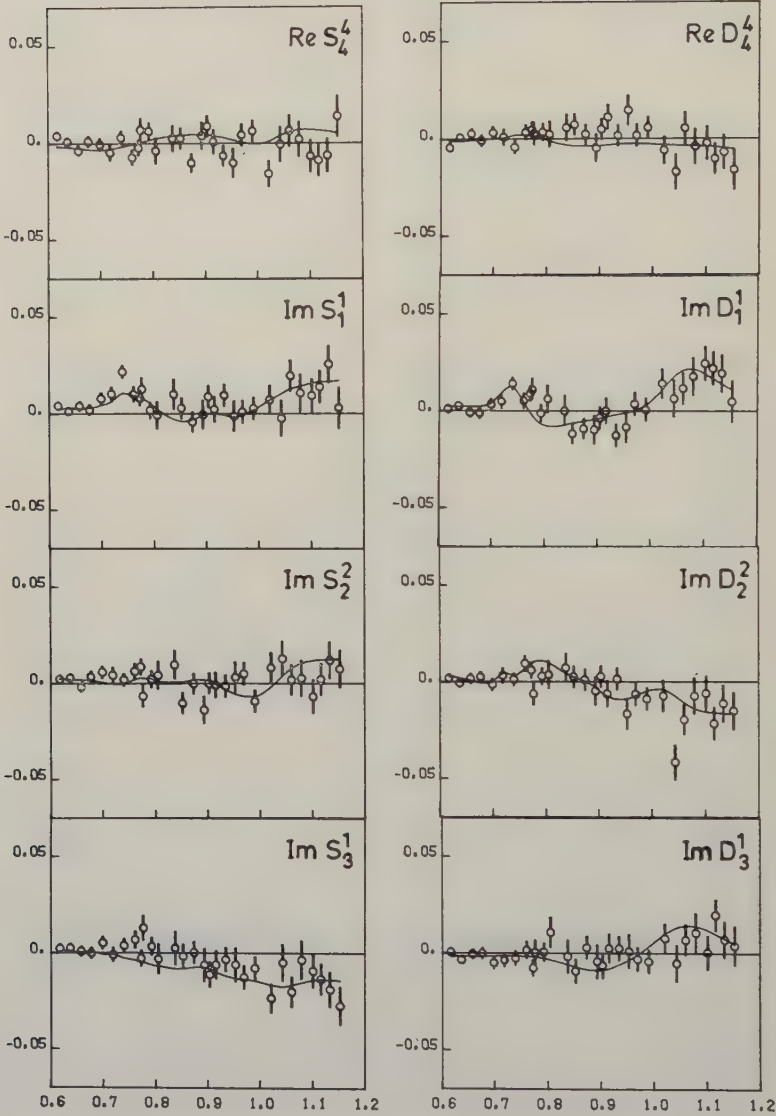


Fig. 6c

d

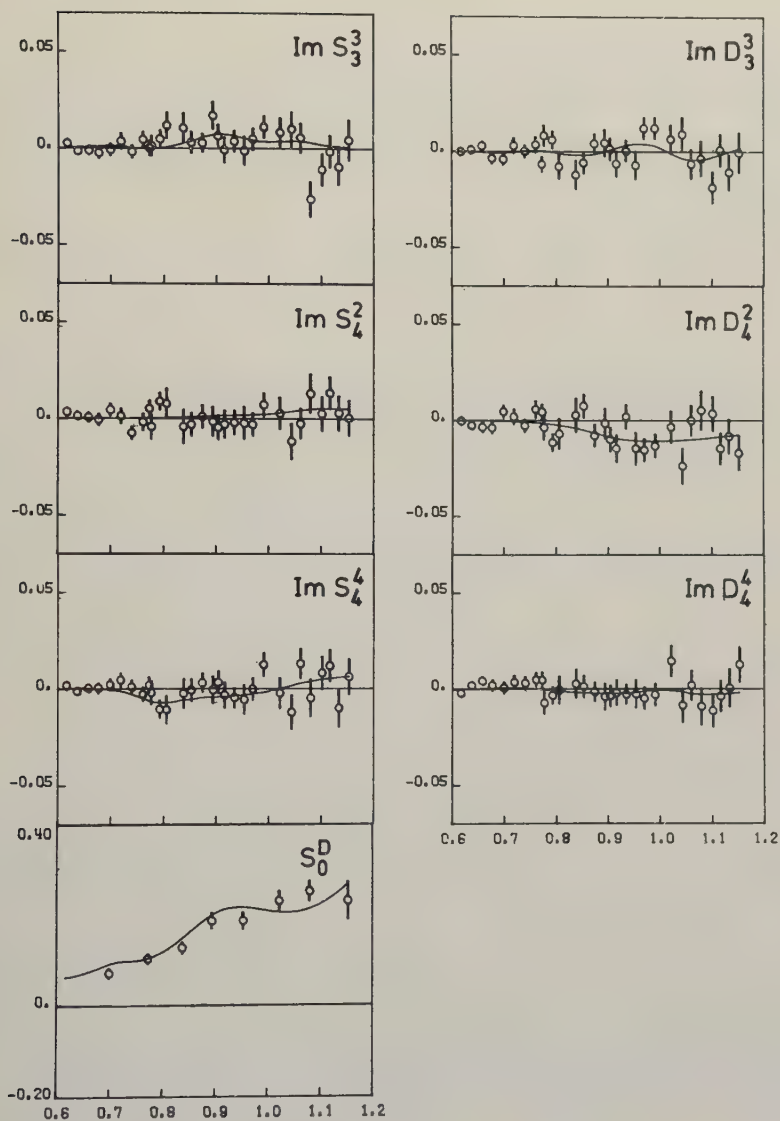


Fig. 6d

Fig. 6. (a, b, c, d) Incident momentum dependence of the real and imaginary parts of the coefficients S_l^m and D_l^m and of the coefficient S_0^D . The curves represent the results of the best fit in partial-wave analysis.

amplitudes of the seven well-known resonances lying in this energy range, together with a crude description of the non-resonant background.

3.1. Formalism

Interferences between $\Sigma^+(1385)\pi^-$ and $\Sigma^-(1385)\pi^+$ in reaction (1) are expected to be important below ~ 0.8 GeV/c. It is thus necessary to use a formalism which takes them into account, such as developed in ref. [1]. In the model formulated by Deler and Valladas, the coefficients S_l^m and D_l^m can be expressed as functions of the partial wave amplitudes T_e :

$$S_l^m = \sum_{ee'} C_{ee'}^S T_e T_{e'}^*, \quad D_l^m = \sum_{ee'} C_{ee'}^D T_e T_{e'}^*.$$

Here e (and e') stands for the set of quantum numbers characterizing a partial wave: initial and final orbital momentum l_i , l_f ; total angular momentum J and isospin I . The complex coefficients $C_{ee'}^D$ and $C_{ee'}^S$ depend on these quantum numbers and the center-of-mass energy. They have been computed at each momentum, taking into account the interferences between $\Sigma^+(1385)$ and $\Sigma^-(1385)$ production amplitudes. These amplitudes are represented by a Breit-Wigner formula with mass-dependent width, such as is described later on for other resonances.

The density of the Dalitz plot is a constraining part of the experimental data which is not contained in the S_l^m and D_l^m coefficients, but which is partially represented by the a_2 coefficient, at least in a first approximation. This coefficient depends only on the square of the partial wave amplitudes, through the expression:

$$a_2 = \frac{\sum_{J, l_f} \alpha_{J, l_f} (J + \frac{1}{2}) [\frac{1}{6} |T_{J, l_f, 0}|^2 + \frac{1}{4} |T_{J, l_f, 1}|^2]}{\sum_{J, l_f} (J + \frac{1}{2}) [\frac{1}{6} |T_{J, l_f, 0}|^2 + \frac{1}{4} |T_{J, l_f, 1}|^2]},$$

where $T_{J, l_f, 0}$ and $T_{J, l_f, 1}$ are amplitudes with isospins 0 and 1; α_{J, l_f} are coefficients given in table 2. This expression is approximate since interferences between both

Table 2

Numerical values of the coefficient α_{J, l_f} relating partial wave amplitudes T_{J, l_f} to the a_2 coefficient of the angular distribution of the decay of $\Sigma(1385)$

J	l_f	Partial wave	α_{J, l_f}
$\frac{1}{2}$	2	SD1	1
$\frac{1}{2}$	1	PP1	1
$\frac{3}{2}$	1	PP3	$-\frac{2}{3}$
$\frac{3}{2}$	0	DS3	0
$\frac{3}{2}$	2	DD3	0
$\frac{3}{2}$	2	DD5	$-\frac{5}{7}$
$\frac{5}{2}$	1	FP5	$\frac{1}{5}$

$\Sigma(1385)$, and between amplitudes corresponding to the same J , but to different l_f are neglected.

3.2. Method of fit

In the energy-dependent fit, the partial-wave amplitudes T have been parametrized as a function of the incident momentum which is the sum of a resonant term, A_R , and a non-resonant one, A_{NR} :

$$T = A_R + A_{NR},$$

where A_R is the usual non-relativistic Breit-Wigner amplitude formula, with energy-dependent width [9]:

$$A_R = \frac{t}{2(E_R - E)/\Gamma - i}.$$

E is the center-of-mass energy, E_R the resonant energy, t the amplitude at resonance, Γ the total width. An interaction radius R of 1 fm has been used to compute the energy-dependence of both the total and the partial $\Sigma(1385)\pi$ width of the resonance according to the centrifugal barrier formula [9].

For A_{NR} , the proximity of the $\Sigma(1385)\pi$ threshold conveys the necessity of using a damping factor in front of the usual linear expression:

$$A_{NR} = \left(\frac{kR B_{lf}}{\sqrt{1 + (kR)^2}} \right)^{\frac{1}{2}} (a + b p_{inc}).$$

Here a and b are the fitted complex parameters; p_{inc} is the incident momentum, k is the final c.m. momentum and B_{lf} the final state centrifugal barrier factor.

The maximum complexity of the S_l^m and D_l^m coefficients led us to restrict the partial waves to the following set, with the usual notation $l_i l_f$, I , $2J$:

SD01, PP01, PP03, DS03, DD05, FP05,

SD11, PP11, PP13, DS13, DD15, FP15.

This corresponds to the lowest value of l_f for a given J and l_i . However the waves DD03 and DD13 were also used in some fits.

The waves DS03, DS13, DD03, DD13, DD05, DD15, FP05 have always been put purely resonant ($A_{NR} = 0$), using masses and widths given in table 3; only the t parameter has been fitted. Waves SD01, SD11 and PP01 had a non-resonant and a resonant term, in which the mass and width have been fitted. Waves PP11, PP03, PP13 and FP15 were always non-resonant.

Finally, it has been checked that the sign convention for composing $I = 0$ and $I = 1$ amplitudes was the same as for the reaction $K^- p \rightarrow \Sigma^\pm \pi^\mp$, namely that:

$$T(\Sigma^\pm(1385)\pi^\mp) = \frac{1}{\sqrt{6}} T_{(I=0)} \pm \frac{1}{2} T_{(I=1)}.$$

Table 3

Results of the best fit. The elasticities x_e quoted here are those of ref. [17] for $\Lambda(1670)$, $\Lambda(1690)$ and $\Sigma(1750)$; of ref. [18] for $\Sigma(1750)$; and of ref. [19] for $\Lambda(1830)$, $\Sigma(1765)$ and $\Lambda(1815)$. x_d is the branching fraction into $\Sigma(1385)\pi$. Quantities in brackets have been kept fixed. Chi-square is 1248 for 896 degrees of freedom

Partial wave	Resonance	Mass (GeV)	Width (GeV)	t	x_e	x_d ($\Sigma(1385) \rightarrow \Lambda\pi$)	Re(a)	Im(a)	Re(b)	Im(b)
SD01	$\Lambda(1670)$	1.665 ± 0.005	0.019 ± 0.005	-0.18 ± 0.05	0.14	0.23	-0.050	-0.072	0.208	-0.005
SD11	$\Sigma(1750)$	1.739 ± 0.010	0.108 ± 0.020	$+0.18 \pm 0.15$	0.12	0.27	+0.587	+1.799	-0.770	-1.886
PP01		1.746 ± 0.010	0.046 ± 0.020	$+0.18 \pm 0.10$			-0.908	+0.620	+0.910	-0.753
PP11							+0.457	-0.246	-0.329	+0.290
PP03							-0.020	0.076	0.139	0.012
PP13							+0.098	+0.218	-0.102	-0.284
DS03	$\Lambda(1690)$	[1.690]	[0.050]	$+0.27 \pm 0.04$	0.18	0.41				
DS13	$\Sigma(1660)$	[1.660]	[0.050]	$+0.11 \pm 0.03$	0.08	0.15				
DD05	$\Lambda(1830)$	[1.830]	[0.100]	$+0.13 \pm 0.03$	0.09	0.19				
DD15	$\Sigma(1765)$	[1.765]	[0.120]	$+0.20 \pm 0.02$	0.45	0.09				
FP05	$\Lambda(1815)$	[1.815]	[0.070]	$+0.27 \pm 0.03$	0.62	0.12				
FP15							+0.203	+0.239	-0.237	-0.322

3.3. Data

A preliminary study has been made with a partial set of data, including S_I^m , D_I^m and the cross section of reaction (2), but lacking information on the density of the Dalitz plot [10]. It turned out, however, that the coefficient a_2 calculated with the best fit under these conditions is inconsistent with the data. Moreover the values obtained for the amplitudes at resonance were not compatible with a preliminary simplified study presented in ref. [11]. This shows that even under our simplifying assumptions fits have to be made with all the available data which are constituted by 938 experimental points, namely: the S_I^m , D_I^m , the a_2 coefficients for reaction (1) and the coefficients S_0^D .

3.4. Results of the fit

Several fits were made, with different parametrizations of the amplitudes, and, for each one, with different starting values. Generally they converged to the same fitted parameters, with comparable chi-squares. The best solution includes a resonant part for SD01, SD11 and PP01. The corresponding parameters are given in table 3 together with the $(\Sigma(1385) \rightarrow \Lambda\pi)\pi$ branching fractions x_d calculated from the elasticities x_e quoted in the caption. Errors have been estimated from the dispersion of the fitted parameters in several fits. The fitted values of the experimental data are shown in figs. 4, 5 and 6, and the amplitudes $T(l_i, l_f, I, 2J)$ are displayed on Argand diagrams in fig. 7.

3.5. Discussion of the results

3.5.1. S-waves. Reasonably good fits have also been obtained with waves SD01, or SD11, or both, put as non-resonant. If both are non-resonant the chi-square increases by about 100 units. Therefore we conclude that at least one of these waves has a resonant part which is not negligible. For masses and widths, the fitted values given in table 3 agree very well with the accepted values of the S-wave resonances, $\Lambda(1670)$ and $\Sigma(1750)$.

3.5.2. PP01 wave. A resonant PP01 wave has been tried to account for the small bump found in the cross section of reaction (1) around 0.880 GeV/c, which corresponds to a suggested P01 resonance. The values obtained for the mass and width are respectively 1.746 GeV and 0.046 GeV, in agreement with the somewhat fluctuant parameters accepted usually for this resonance. But the decrease in chi-square, which is about 30, is not large enough to be considered as significant. It seems therefore that this P01 resonance is not compelling to explain the data.

3.5.3. D3 waves. Resonances in DS03 and DS13 waves have always been put in the fits, because their absence gives a bad chi-square. Values of the amplitude at

resonance remain fairly well constant in all fits. The same resonances have also been tried as DD03 and DD13, with or without DS3 waves; in all trials the values of t for DD03 and DD13 are found to be much smaller than those for DS03 and DS13. Although a definite statement cannot be made, it appears that only the lowest final state orbital momenta are needed to describe the D3 amplitudes.

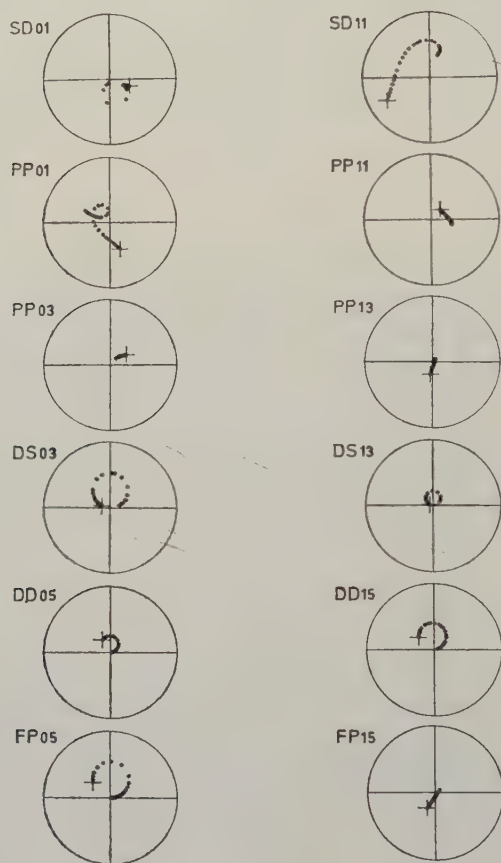


Fig. 7. Argand diagrams of the various partial wave ($l_i, l_t, I, 2J$) amplitudes obtained in the partial wave analysis. The crosses lie at the highest c.m. energy, 1.865 GeV.

3.5.4. D5 waves. The amplitudes of the $\Lambda(1830)$ and $\Sigma(1765)$ are found to be almost invariant in all the fits which have been performed, and correspond to significant couplings into $\Sigma(1385)\pi$.

3.5.5. F5 waves. The same remark as above applies to $\Lambda(1815)$. The FP15 wave has been parametrized as non-resonant, since the corresponding resonance, $\Sigma(1915)$, is outside the energy range of the fit.

4. SU(3) interpretation of the results

In SU(3) symmetry two coupling constants (corresponding to the two angular momenta involved in the decay) are generally required to explain the decay of a baryonic resonance into a pseudo scalar meson and a $\frac{3}{2}^+$ baryon belonging to the well-known decuplet. In this analysis the higher l_f has generally been neglected on the basis of angular barrier arguments and that could of course modify the coupling constant to the decuplet g_{10} which may be extracted from these results.

With this assumption, we have derived the coupling constants g_{10}^A and g_{10}^Σ for the $\frac{1}{2}^-$, $\frac{3}{2}^-$, $\frac{5}{2}^-$ and $\frac{5}{2}^+$ octets from the Λ and Σ partial widths $\Gamma_{\Sigma(1385)\pi} = x_d \Gamma/f$ (f is the branching fraction of $\Sigma(1385)$ into $\Lambda\pi$ taken equal to 0.89 [20]) by the formula:

$$\Gamma_{\Sigma(1385)\pi} = (cg_{10})^2 k B_{l_f} \frac{0.938}{E_R},$$

where c is the relevant $\{8\} \otimes \{10\}$ Clebsch-Gordan coefficient. The values of the g_{10}^A and g_{10}^Σ coupling constants are presented in table 4. Their relative sign has been deduced from the sign of the resonant amplitudes t and the accepted values of the octet coupling constants [12]. As it is difficult to evaluate reliable errors on $\Gamma_{\Sigma(1385)\pi}$, that is on Γ , t and x_d , and also as the centrifugal barrier used is somewhat arbitrary, no error is given on the values of g_{10}^A and g_{10}^Σ . A tentative evaluation of these errors would be about 25% of the coupling constants values. We have also reported in table 4, the value of g_{10}^N extracted from a partial wave analysis of the reaction $\pi N \rightarrow \pi \Lambda(1236)$ [12, 13].

The following remarks are appropriate:

(a) The values of g_{10}^A and g_{10}^N for the $\frac{5}{2}^+$ multiplet are in good agreement.

Table 4
 $\{8\} \otimes \{10\}$ SU(3) coupling constants for the $\frac{1}{2}^-$, $\frac{3}{2}^-$, $\frac{5}{2}^-$, $\frac{5}{2}^+$ octets

Multiplet	$\frac{1}{2}^-$ a)	$\frac{3}{2}^-$	$\frac{5}{2}^-$	$\frac{5}{2}^+$
$\Gamma_{\frac{1}{2}^-(1385)\pi}^A$ (MeV) ^{c)}	4.9	23.	21.4	9.4
$\Gamma_{\frac{3}{2}^-(1385)\pi}^\Sigma$ (MeV) ^{c)}	32	8.4	12.1	
g_{10}^A	+0.8	-0.58 ($\theta = -23^\circ$) ^{b)} -0.69 ($\theta = -39^\circ$)	-0.69	-0.33
g_{10}^Σ	+2.6	-0.71	+1.38	
g_{10}^N [12, 13]	not seen	-0.47	+1.2	-0.32

a) The mixing between $\Lambda(1405)$ and $\Lambda(1670)$ has been neglected.
 b) The absolute value of g_{10} obtained from the $\Lambda(1520) \rightarrow \Sigma(1385)\pi$ partial width [16] is 1.13 for $\theta = -23^\circ$ and 0.69 for $\theta = -39^\circ$
 c) The decay of $\Sigma(1385)\pi$ into $\Sigma\pi$ with a branching fraction of 0.11 [20] has been taken into account in this table.

(b) In the case of the $\frac{5}{2}^-$ octet, the relative sign between $t_{A(1830)}$ and $t_{\Sigma(1765)}$ is in contradiction with what is expected from the accepted values for g_D and g_F [12, 14]. The values and the signs of g_{10}^{Σ} and g_{10}^N are quite compatible, but they disagree with g_{10}^A . This value is derived from the small DD05 amplitude, which may have been incorrectly described by a pure resonance, perhaps neglecting an important background.

(c) For the $\frac{3}{2}^-$ nonet, the situation is somewhat clarified. The absolute value of the mixing angle calculated from the decays $\Lambda(1520) \rightarrow \Sigma(1385)\pi$ [16] and $\Lambda(1690) \rightarrow \Sigma(1385)\pi$ turns out to be about 39° , as compared to $(23 \pm 4)^\circ$ obtained from the two-body decays' fit [12]. The value of g_{10}^A has been calculated for these two values of θ . It can be seen that the results obtained seem to be in agreement with a simple SU(3) description without requiring another $\frac{3}{2}^-$ octet [15]. Here, a reasonable agreement is obtained between g_{10}^A , g_{10}^{Σ} and g_{10}^N .

(d) The coupling constants g_{10}^A and g_{10}^{Σ} for the $\frac{1}{2}^-$ octet have the same sign, and the difference between their absolute values may be explained by the large uncertainties in the elasticities of these resonances. Furthermore, we should like to point out that the situation of this octet is not clearly understood, and that no $\Delta\pi$ decay of $N^*(1535)$ has yet been found.

5. Conclusions

Our analysis shows that all the seven well accepted resonances which are formed in the energy region under consideration are strongly coupled to the $\Sigma(1385)\pi$ channel. It can be shown that this channel and the two-body decays saturate within errors the total width of $\Lambda(1670)$ and $\Lambda(1690)$. For the $\Sigma(1765)$ and $\Lambda(1815)$ these decays account for about 80% of their total width, whereas for $\Sigma(1660)$, $\Sigma(1750)$ and $\Lambda(1830)$ there is plenty of room for other decay modes not yet detected.

The resonant amplitudes determined in this experiment, and the $\Delta\pi$ amplitudes reported in ref. [12] are generally in agreement with SU(3) for the $\frac{3}{2}^-$, $\frac{5}{2}^-$ and $\frac{5}{2}^+$ multiplets. However, it must be noted that although the situation of the $\frac{3}{2}^-$ nonet is considerably improved, a new problem arises for the $\frac{5}{2}^-$ octet, namely that the relative sign of the amplitudes for $\Lambda(1830)$ and $\Sigma(1765)$ does not agree with SU(3) predictions [12, 14]. It should be pointed out, however, that at present this disagreement should not be taken too literally as a possible failure of SU(3), since our analysis relies on several rather simplifying hypotheses which may not be verified for this octet.

The authors would like to thank all the other members of the CERN-Heidelberg-Saclay groups for their helpful collaboration.

References

- [1] B. Deler and G. Valladas, *Nuovo Cimento* 45 (1966) 559.
- [2] R. Armenteros et al., *Nucl. Phys.* B8 (1968) 233.
- [3] R. Armenteros et al., *Nucl. Phys.* B18 (1970) 425.
- [4] R. Armenteros et al., *Nucl. Phys.* B21 (1970) 15.
- [5] E. Bracci et al., Report CERN/HERA 72.2 (1972).
- [6] J.H. Bartley et al., *Phys. Rev. Letters* 21 (1968) 1111;
W.H. Sims et al., *Phys. Rev. Letters* 21 (1968) 1413.
- [7] A. De Bellefon et al., *Nuovo Cimento* 7A (1972) 567.
- [8] D. Colley et al., *Nucl. Phys.* B31 (1971) 61.
- [9] R.D. Tripp, Baryon resonances, CERN 65-7.
- [10] J. Prevost et al., Amsterdam Conf., 1971.
- [11] R. Armenteros et al., *Z. Phys.* 202 (1967) 486.
- [12] A. Barbaro-Galtieri, LBL 1366 (1972);
I. Butterworth, Proc. 1973 Aix en Provence Int. Conf. on elementary particles, p. 193.
- [13] D.J. Herndon et al., LBL 1065 (1972).
- [14] D.E. Plane et al., *Nucl. Phys.* B22 (1970) 93.
- [15] D. Faiman and D.E. Plane, *Phys. Letters* 39B (1972) 358.
- [16] T. Mast et al., *Phys. Rev. Letters* 28 (1972) 1220.
- [17] R. Armenteros et al., *Nucl. Phys.* B14 (1969) 91.
- [18] B. Conforto et al., *Nucl. Phys.* B34 (1971) 41.
- [19] R. Armenteros et al., *Nucl. Phys.* B8 (1968) 195.
- [20] Particle Data Group, *Rev. Mod. Phys.* 45 (1973) 1.

